A Simple and Quick Chilled Water Loop Balancing for Variable Flow System

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ABSTRACT

For many modern buildings, the chilled water loops and risers are equipped with variable speed pumping systems. How to quickly balance the loop or riser to satisfy the cooling requirement and reduce energy consumption is a very interesting topic today. In this paper, a method for simple and quick balancing of the chilled water risers for a large medical facility has been developed and implemented. Through water loop commissioning, the cold air temperature is maintained very well and the energy consumption for the pumping system is reduced by about 40%.

Key words: chilled water, loop, riser, balancing, commissioning, cold deck, pump,

INTRODUCTION

Variable flow pumping systems are becoming more prevalent in the chilled water loops or risers for new buildings. Also, more and more constant volume chilled water systems are being converted to the variable flow systems as major energy retrofit items for existing buildings [Zhu, Liu, et al., 1997; Zhu, Turner and Claridge, 1999;]. This gives the building owner, facility engineers or HVAC operators more opportunities to run the chilled water system more efficiently. Generally, the pump speeds are controlled by the EMCS or a stand-alone controller to maintain the differential pressure setpoints or the differential pressure plus the return water temperature setpoints. The implementation of the improved setpoints to control the chilled water loops can greatly benefit the energy savings of the HVAC systems [Zhu, Liu and Claridge, et al., 1997; Zhu, Liu, et al., 1999; Liu, Zhu, et al., 1997; Claridge, Liu and Zhu, et al., 1996]. Even though the chilled water systems are equipped with variable speed pumps, some of the variable flow chilled water loops or risers are still balanced in the traditional way. Manual balancing valves are still heavily used to balance the water flow to different floors and to the cooling coils.

During the building commissioning process, the authors have developed a simple and quick approach to balance the variable flow chilled water risers. This paper presents the approach, and the results are shown for the building commissioned.

APPROACH AND APPLICATION

Approach

The traditional method of balancing the chilled water loop sets the variable speed pump

adjusted to make sure that there is design flow through each coil and that a certain differential pressure is maintained for each floor, e.g. 10 to 20 psi. For most cases, through traditional balancing, the manual balance valves are adjusted to a partially open position and will remain in that position until somebody adjusts it later. Sometimes, the valves remain at 50% open or less for each floor. The chilled water requirement or the cooling loads are subject to change, depending on the weather conditions and the internal load ratio. Most of the time, the cooling load is under partial load conditions. Due to the partial opening of the balance or manual valves, the pump power reduction for variable speed pumps will be much less than expected. The traditional approach to system balancing thus negates some of the benefits of installing variable speed drives.

Through the commissioning process, the authors developed a new approach to quickly balance the chilled water risers if the risers are equipped with VFDs. The new approach of balancing the variable flow chilled water risers is:

1. Fully open the entire manual balancing valves for each coil on each floor.
2. Optimize the differential pressure (ΔP) setpoints based on the riser layout and the ΔP sensor location.
3. After the implementation of the new setpoints, check the cold deck temperature for each coil, the ΔP for the furthest coils, critical coils, or any special coils. Make sure that there is good cold deck temperature control and enough ΔP for each coil.
4. Identify each faulty sensor and valve and any control problems for the coil control valve. Repair any that are malfunctioning.
5. Fine-tune the setpoints based on the actual load conditions and the control results.

Application

Building Information

The building is a multi-functional, state-of-the-art medical center with a gross area of 1,470,000 square feet. It was built in 1995 with a modern EMCS control for the HVAC systems. The building was mostly occupied in late 1996. The whole complex primarily consists of outpatient clinic rooms, pharmacy, nuclear medicine, ICUs, CCUs, surgical areas, inpatient beds, diagnostic areas, research labs, animal holding areas, offices, cafeteria, computer rooms, classrooms and an auditorium. The building is maintained by an outside contractor, and they do a very good job in handling the day-to-day operational problems of such a large medical facility.

HVAC System Information

There is a central chiller plant, which provides the chilled water to the complex. The loop pumps pump the chilled water to the building entrance. A total of 14 chilled water risers with 28 building chilled water pumps pump the chilled water to the entire building which has 90 major air handling units (AHUs) and some small fan-coils units. All of the building chilled water pumps are equipped with variable speed drives (VFDs). Most of the AHUs are double duct units. The HVAC systems are controlled by a modern EMCS.

Chilled Water Risers

The entire complex includes five major buildings and a research building. There are a total of 14 risers for the complex. Each riser has two variable speed pumps. Only one pump is on line for each riser with the other in standby, according to the lead/lag control sequence. The differential pressure (ΔP) is maintained by modulating the VFD of the chilled water pumps. A typical riser diagram is shown in Figure 1. The differential pressure sensor (ΔP sensor) is located about 10 to 20 feet away from the far-end cooling coil of the AHU on the top floor for each riser. The risers were balanced after the systems were built.

Measurement and Inspection Results

The authors performed a detailed inspection and took measurements for all the riser systems. Measurements include loop ΔP, building ΔP, far-end coil ΔP or riser control ΔP (sensor location), each manual balance valve status, VFDs speed and cold deck temperature.

The following major issues were found:

1. The manual balance valves were balanced to the position of 30% to 60% open for each coil or each floor.
2. Only one coil after the ΔP sensor for each riser.
3. VFD speed ranged from 41Hz to 60Hz.
4. The ΔP setpoint ranged from 13 psi to 26 psi for different risers.
5. The measured ΔPs were close to the setpoint values.
6. Most of cold deck temperatures were controlled very well; however, 13 AHUs had cooling coils that were with 100% open of control valve or had cold deck temperatures higher than the setpoints.

Analysis and Implementation of Balancing

From the inspection and measured results, it was discovered that the manual balance valves were open about 50% on average, and the ΔP setpoint is primarily for the last coil on the top floor for each riser. The authors determined to use a new approach to quickly balance the risers. Based on the sensor location and condition of the coil and valve, it was determined a constant value can be used for the ΔP setpoint and the range should be from 6 psi to 13 psi for different risers.

From September 24 to October 1, 1998, the authors followed the developed procedures and completed the balancing of the 14 risers for the entire building. During the balancing process, we not only opened the manual valves of the major

AHUs, but also the small FCUs. The new ΔP setpoints were implemented through the EMCS. The cold deck temperatures were checked before and after the balancing.

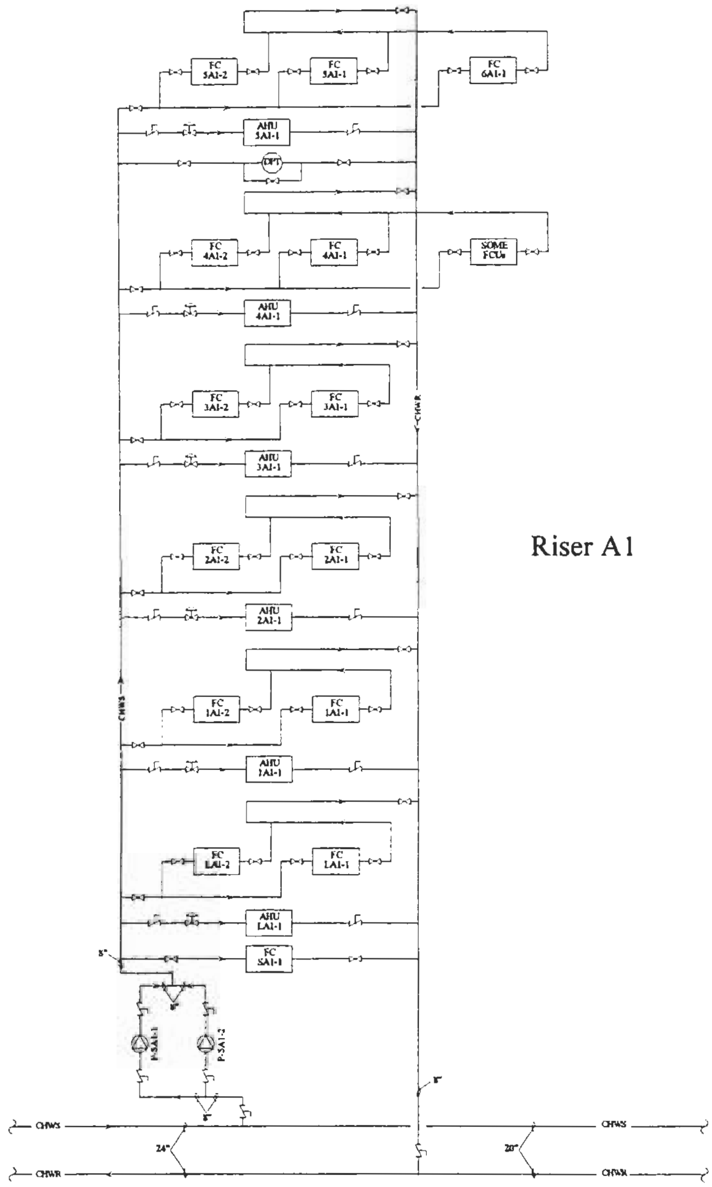

Figure 1. Typical chilled water riser for the building

Troubleshooting and Fine-tuning

From the EMCS readings and field-measured results, the following problems were identified:

1. Cold air temperature sensor problem:

For AHUs 1A5, 2A4, 1M2, 1M4, and 2M4, the sensor readings were higher than the actual temperature. Consequently, the valves were full open, but were maintaining excessively low cold air temperatures. This problem was solved after calibrating the sensors and balancing the systems.

2. Problem of increased cooling load:

For AHU 8A2, the coil could not maintain the cooling load, we investigate the problem and found there was excessive outside air intake (much more than the design value). Consequently, the ΔP setpoint was set to 13 psi on this A2 riser as a temporary measure. After the air flow correction, the ΔP setpoint could be adjusted.

For AHU 3B2, the coil cooling load was increased significantly because of excessive outside air intake (over 50% above the design value).

Consequently, the chilled water valve was wide open and could not meet the load. After the air flow correction, the ΔP setpoint could be set at 8 psi or lower.

3. Control range settings problem:

For 4M3, 3B2, 7B2, LR4, LA4 and 1A5, the control ranges for the PID loop were insufficient. They were also corrected following the balancing.

Measured Results from New Balancing

The results from the new balancing are shown in Table 1.

After the balancing, the chilled water flows all remained at the same level as before, the cold air temperatures were maintained at the setpoints, and the pumping power consumption was reduced by approximately 40% or 80 kW.

Table 1. Summary of chilled water system condition before and after reset and estimated savings

Riser	Before Reset				After DP Reset				% of rated HP	Rated HP
Name	DP setpoint	Time	DP meas.	Pump Hz	DP setpoint	Time	DP meas.	Pump Hz	Savings	
C11/C12	13	14:00	13.1	41.3	6	10:20	6.2	27.7	23%	15
C21/C22	16	14:20	16.1	49.1	7	15:50	7	33.8	37%	15
M1	15.2	11:00	15	45	7	13:40	7	29.1	31%	15
M2	25	11:10	25	60	8	13:45	8	37	77%	20
M3	25	15:00	24.5	60	8	16:00	7.8	35.4	79%	20
M4	26	15:10	24	59.8	8	16:06	8	40	69%	20
A1	20	9:00	20.5	50.5	8	10:50	8	33	43%	20
A2	16	13:15	16.2	40.3	13	16:19	13.1	36.7	7%	40
A3	15.2	11:20	15	43.8	8	15:00	8	32	24%	20
A4	16.2	13:50	16.3	53	12	13:16	12	45.3	26%	15
B1	14	14:00	13.6	50.7	8	14:30	8	42.7	24%	15
B2	17	14:00	17	55.7	9	13:42	8.7	42.2	45%	15
R1/R2	14	11:40	14	54.7	8	15:50	8	44.1	36%	15
R3/R4	16	11:45	15	50.4	8	15:54	7.1	36	38%	25
Ave/Tot									40%	270
Total Saving									108hp (80kw)	

CONCLUSION

A quick and simple balance approach to balance the variable chilled water riser or the chilled water loop was developed by the authors and was also applied to a commissioning project. The approach considers the real system layout and the operating condition of the riser or loop. When compared to the traditional balancing methods, this new approach can reduce the pumping power consumption much more and make the VFD conversion payback much shorten. If the ΔP sensor is located on 2/3 piping distance down stream from the pump, the reset schedule of ΔP is recommended. The reset ΔP can be based on the load condition or outside air temperature.

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